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NUTRITIONAL VALUE OF WINTER FOODS FOR WHOOPING CRANES

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ABSTRACT.—We measured metabolizable energy and digestibility of Whooping Crane (*Grus americana*) winter foods (blue crab [*Callinectes sapidus*]), common *Rangia* clam (*Rangia cuneata*), wolfberry fruit (*Lycium carolinianum* [wolfberry]), and live oak acorn (*Quercus virginiana* [acorn])] with feeding trials to captive-reared Whooping Cranes. Apparent metabolizable energy coefficients (expressed as %) were for crab (34.1), *Rangia* clam (75.0), wolfberry (44.8), and acorn (43.2). Digestion coefficients for protein were lower for plant foods (48.9 and 53.4) than for animal foods (69.4 and 75.2). Digestion coefficients for total lipid differed among foods: highest and lowest lipid digestibility was for acorn (87.2) and wolfberry (60.0), respectively. We also determined total energy and percent protein and lipid of the four foods and stout razor clam (*Tagelus plebeius*); gross energy was 2–5× higher for acorn and wolfberry on a dry-weight basis than for blue crab and stout razor clam. Crude protein was 2–3× higher for blue crab than for wolfberry and stout razor clam. Wolfberry ranked the highest of five foods for metabolic energy and total lipid nutrient availability per kg of food ingested, and blue crab ranked highest for crude protein availability. *Received 1 December 1995, accepted 10 April 1996.*

Investigators have documented foods eaten by Whooping Cranes on their Texas Coastal wintering ground (Aransas National Wildlife Refuge [ANWR]). They have determined that Whooping Cranes rely on blue crabs (*Callinectes sapidus*), stout razor clams (*Tagelus plebeius*), wolfberries (*Lycium carolinianum*), and acorns (*Quercus virginiana*) for their energy and nutrient needs (Stevenson and Griffith 1946; Allen 1952, 1954; Shields and Benham 1969; Uhler and Locke 1970; Blankinship 1976; Hunt and Slack 1987, 1989). In order to determine if winter food resources are adequate, managers should understand metabolizable energies, nutrient digestibilities, and nutritional values of these foods. Our objectives were to determine (1) metabolizable energy and nutrient digestibility coefficients for winter Whooping Crane foods, by feeding them to captive Whooping Cranes, and (2) the energy and nutritional content of these foods.

METHODS

We conducted feeding trials with captive-reared Whooping Cranes in spring 1994 at Patuxent Environmental Science Center (PESC), Laurel, Maryland. Because of the endan-

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gered status of Whooping Cranes (U.S. Fish and Wildl. Serv. 1994), we used captive-reared birds in our digestibility studies. Cranes were raised on pelleted diets, could not be induced to eat whole foods voluntarily, and unacceptable risks were associated with forced feeding. The amount of wild foods we were able to collect influenced the amount and length of time food was fed to individual birds. The amount of time captive birds could be maintained under experimental conditions was also limited because we were concerned about behavioral problems and risk of injury. Therefore, treatment diets were mixed with control diets and fed to captive Whooping Cranes during short time periods. Wild foods were provided in pelleted feeds at a 30% level of substitution because of concerns that captive cranes might be adversely affected by eating feeds with higher levels of wild foods and might reduce feed consumption at levels higher than 30% (Muztar et al. 1977). Thus, we were unable to conduct validation trials using 100% wild foods.

We housed four subadult (1-yr-old) and one adult (3-yr-old) Whooping Cranes in adjacent 3.4 × 2.7 × 3.1-m indoor pens at the PESC during feeding trials from 2 March to 27 April 1994. Connected to each indoor pen was a 9.1 × 2.9 × 2.9-m outdoor runway. Each indoor pen was equipped with a gravity feeder, water bucket, and a bowl for granite grit. Floors were covered with smooth rubber matting to collect excreta. Cranes were allowed to move between indoor and outdoor runways on days when they were not fed study diets and were housed indoors at night. Indoor photoperiod was maintained at 10.5D:13.5L, and indoor temperature ranged from 13°C to 25°C. Cranes were weighed to the nearest 100 g with a spring scale (1) when first moved to the Propagation Building, (2) six days after the initial move, and (3) when the study was completed. Daily at 06:00, we fed 1000 g each of blue crab, *Rangia* clam, acorn, and reference feeds and 400 g of wolfberry feed.

We collected acorns, blue crabs, wolfberries, and *Rangia* clams from Whooping Crane foraging areas on the ANWR Blackjack Peninsula and Matagorda Island, Texas, and adjacent coastal areas between 8 October 1993 and 17 February 1994 (Labuda and Butts 1979, Stehn 1994b, U.S. Fish and Wildl. Serv. 1994). Acorns were also collected at College Station, Texas, to supplement acorns collected at the ANWR. Whooping Cranes prefer stout razor clams (Blankinship 1976), but we could not collect sufficient numbers; instead, we collected the less preferred *Rangia* clam for our feeding trials. Foods were stored at −20°C until they were dried at 55°C for 24–36 h and ground in a Wiley or Hammer mill to pass through a 20-mesh screen. Study diets were prepared by combining 30% dry weight of blue crab, *Rangia* clam, wolfberry, or acorn with 70% commercial crane breeder feed. We added bentonite (0.5%) to each diet as a hardening agent and an inert tracer, chromic oxide (0.5%), to determine metabolizable energy and nutrient digestibility coefficients (Karasov 1990). Moistened diets were mixed in a Hobart food mixer, formed into pellets (0.48-cm diameter) using a Hobart food processor, and air dried and stored in plastic bags at 5°C until feeding.

Apparent metabolizable energy coefficients (MEC*) for test feeds were determined using the equation of Karasov (1990): $MEC^* = [GE_i - (\%T_i/\%T_e)GE_e]/GE_e$; where GE_i and GE_e equal, respectively, the gross energy content (cal·g^{-1} dry mass) of feed (intake) and excreta, and $\%T_i$ and $\%T_e$ equal, respectively, the percent of chromic oxide tracer in feed and excreta. Apparent digestible energy coefficients for test feeds (DEC*) were determined by subtracting percent gross energy of uric acid in excreta (% uric acid multiplied by 2730 cal·g^{-1}) (Lide 1994) from total gross energy of excreta (GE_e) and substituting energy excreta (minus uric acid energy) into the equation for MEC*. Individual MEC*s for test ingredients were determined by equation 2: $MEC^*_i = {}^{100}/_{30} \times (MEC^*_f - [0.7 \times MEC^*_r])$; where MEC^*_i equals the MEC* for the test ingredient, MEC^*_f equal the MEC* for the test feed (feed with test ingredient added), and MEC^*_r equal the MEC* for the reference feed (indicator-marked crane breeder feed) (Wilson and Poe 1985). Apparent digestible energy coefficients for test ingredients (DEC^*_i) were determined by substituting energy excreta (minus uric acid energy)

into the equation for MEC^*_i, where DEC^*_f equal the DEC* for the test feed and DEC^*_r equal the DEC* for the reference feed: $DEC^*_i = (100/30) \times [DEC^*_f - (0.7 \times DEC^*_r)]$.

Apparent dry matter, crude protein, and total lipid digestibility coefficients for test feeds and reference feed (ADC_f) were determined using an index equation by Lloyd et al. (1978):

$$ADC_f = 100 - \left[100 \times \frac{(\%\ \text{Indicator in feed})}{\%\ \text{Indicator in feces}} \times \frac{(\%\ \text{Nutrient in feces})}{\%\ \text{Nutrient in feed}}\right]$$

on the basis of the ratios of indicator in feed and feces and nutrient in feces and feed. Apparent digestibility coefficients for test ingredients (ADC_i) were determined by substituting apparent dry matter, crude protein, and total lipid digestibility coefficients for test feeds and reference feed into equation 2. Digestible protein for test feeds was determined after subtracting uric acid nitrogen in excreta from total Kjeldahl nitrogen in excreta (Rotter et al. 1989).

MEC*s for wild foods with low digestibilities have been shown to be low and in error for waterfowl fed mixed diets (Karasov 1990). However, Muztar et al. (1977) found that apparent dry matter digestibility and apparent metabolizable energy values were higher at the 30% level of substitution than at 10%, 20%, or 40% for alfalfa and five species of aquatic plants and that 30% substitution agreed most closely with regression methods to predict digestibility. Our model for determination of MEC* is based upon the assumption that relations between MEC* values are additive and that there are no synergisms or associative effects for MEC* and nutrient digestibilities due to mixing feed ingredients (Cho et al. 1982, Wilson and Poe 1985).

Diets were fed following a Latin Square design with five, four-day feeding trials. We fed cranes an unmarked breeder diet during a three-day rest period between trials to allow them to excrete all indicator-marked food. Whooping Cranes were held indoors during feeding trails except for four, 30–45-min periods starting at 06:00, 10:00, 14:00, and 18:00 when they were moved outdoors while we collected excreta from the rubber matting and cleaned floors. Fecal samples were collected separately for each bird and for each collection period from indoor pens; samples for each bird and collection period were pooled. Samples collected on days three and four of each feeding trial were used to estimate metabolizable energy and digestibility coefficients. We used change in indicator concentration on the first day indicator-marked diets were fed to evaluate rate of food passage (length of time unmarked feed was retained in the gut).

We collected samples of blue crabs, *Rangia* clams, wolfberries, acorns, and stout razor clams from six different sites on the ANWR (Stehn 1994b, U.S. Fish and Wildl. Serv. 1994). Each collection site was 1–10 ha depending on the relative density and distribution of foods collected, and one food type was collected. We collected nine samples of each food from points on transect lines located at random within each collection area. Sample collections of food items included (1) acorns—8–20 of varying sizes from ≥five plants from Dagger Point and (2) along East Shore Road to the west of Sundown Bay, (3) stout razor clams—10–20 individuals 3–4 cm long from Cedar Lake, Matagorda Island, (4) *Rangia* clams—8–10 individuals 3–5 cm long from Indian Head Point, St. Charles Bay, (5) wolfberries—>50 berries from ≥10 different plants from Sundown Bay, and (6) blue crabs—2–3 crabs (carapace width >10 cm) from Long Lake.

We multiplied average nutrient values for foods by the appropriate digestibility coefficients and ranked foods for available nutrient on a dry-weight basis. Digestion coefficients for *Rangia* clam have been used in calculations for stout razor clam, assuming that digestibilities for these clam species are similar. Ripe acorns collected from Dagger Point had fallen to the ground and were scorched during a prescribed burn several days before they

were collected and represented the type and quality of acorns Whooping Cranes ate (Hunt 1987). We used nutrient values of these acorns in food quality calculations.

Nutritional analyses were conducted using fresh excreta samples (lipid analysis) and dried ground excreta, feed, and food samples. Digestibility calculations for excreta and feed nutrient are expressed on a dry-matter basis corrected to standard drying time (3 h) and temperature (125°C) (Pomeranz and Meloan 1987). Calculations for food nutrient and total energy and nutrient availability of whole foods are expressed on a dry-weight basis.

Gross energy was determined using a Parr micro-bomb adiabatic calorimeter. Gross energy for *Rangia* clam was too low to be accurately determined by bomb calorimetry, and energy values were determined by multiplying percent crude protein by 4000 $cal \cdot g^{-1}$ and percent total lipid by 9000 $cal \cdot g^{-1}$ and adding the results. Total nitrogen was determined by the micro-Kjeldahl method (Helrich 1990). Crude protein was calculated by multiplying total Kjeldahl nitrogen by 6.25. Total lipids were determined by chloroform/methanol extraction for samples homogenized 4 min in a mechanical homoginizer (Folch et al. 1957). Total lipid in freshly homogenized foods was 6% less than for dried ground foods, and total lipid in fresh excreta samples was 4% less than for dried ground excreta samples. Drying foods and excreta at low temperatures and grinding did not lower lipid yield, but enhanced lipid yield compared to extraction of fresh samples. Uric acid was determined colorimetrically for dried excreta samples (Marquardt 1983). Chromium was determined by atomic absorption spectrophotometry after excreta samples were ashed in a muffle furnace and digested in nitric acid (Helrich 1990). Ash was determined by combusting dried samples for 4 h at 500°C in a muffle furnace (Helrich 1990). Total phenols were determined colorimetrically using a gallic acid standard for dried acorn and wolfberry samples extracted 30 min in 70% aqueous acetone (Singleton and Rossi 1965, Hagerman 1988). We determined chitin in blue crabs by sequential acid and alkali digestions (Black and Schwartz 1950).

Each bird was considered the unit of replication for statistical analysis of metabolizable energy and digestibility coefficients. Metabolizable energy and nutrient digestibility coefficients were analyzed for ranked data by three-way Kruskal-Wallis ANOVA (GLM procedure, SAS System) to test for the effects of study feed, Whooping Crane, and feeding trial on each variable. Kruskal-Wallis and Wilcoxon tests (SAS System) were conducted using ranked data to test for nutrient differences between feed ingredients and foods collected from Whooping Crane foraging areas. We compare nutrients of foods collected from Whooping Crane foraging areas by Kruskal-Wallis tests. Tukey's means comparison procedure was used for the separation of means when ANOVA results were significant. Means differences are reported at $P < 0.05$.

RESULTS

Food consumption rarely exceeded 200 $g \cdot day^{-1}$, indicating that sufficient feed was provided to study birds. Study birds maintained body weight during feeding trials from 0–2.3% of their body weight at six days after the initial move. Differences of nutrient levels between test ingredients used in feeds and nutrients in food samples (for the same foods) were less than 10% but were significant in several instances (Table 1). At difference levels of 10%, nutrients in test ingredients were representative of nutrients in foods eaten by wild Whooping Cranes.

Chromic oxide indicator in fecal samples collected at 18:00 EST on day 1 of each feeding trial was 937× higher than indicator in fecal samples collected prior to first exposure to indicator-marked study feeds at

TABLE 1

GROSS ENERGY (kJ·g $^{-1}$), AND PERCENT ASH, CRUDE PROTEIN, AND TOTAL LIPID FOR TEST INGREDIENTS AND FOODS COLLECTED FROM THE ARANSAS NATIONAL WILDLIFE REFUGE (DRY-MATTER BASIS)[a]

Food item/location	Gross energy	Ash	Crude protein	Total lipid
Live oak acorn:				
Test ingredient	20.101 ± 0.174(5)A	2.64 ± 0.02(9)A	4.82 ± 0.03(9)A	6.99 ± 0.10(9)A
East Shore Road	19.076 ± 0.158(5)B	2.62 ± 0.13(9)A	4.46 ± 0.08(9)B	5.45 ± 0.36(9)B
Dagger Point	18.799 ± 0.032(5)B	2.37 ± 0.12(9)A	4.55 ± 0.15(9)B	3.53 ± 0.21(9)C
Rangia cuneata:				
Test ingredient	0.380 ± 0.013(5)A	96.50 ± 0.03(9)B	1.71 ± 0.03(9)A	0.24 ± 0.02(9)A
Indian Head Point	0.326 ± 0.015(5)B	96.87 ± 0.04(9)A	1.44 ± 0.02(9)B	0.24 ± 0.03(9)A
Wolfberry fruit:				
Test ingredient	20.953 ± 0.022(5)B	9.47 ± 0.51(9)A	16.75 ± 0.03(9)B	10.16 ± 0.28(9)B
Sundown Bay	21.430 ± 0.057(5)A	7.01 ± 0.07(9)B	19.46 ± 0.31(9)A	13.38 ± 0.19(8)A
Blue crab:				
Test ingredient	10.514 ± 0.088(5)A	50.03 ± 0.13(9)A	38.27 ± 0.16(9)B	4.35 ± 0.04(9)A
Long Lake	11.947 ± 0.415(5)A	43.59 ± 0.97(9)B	41.89 ± 0.72(9)A	5.28 ± 0.64(9)A

[a] For each food and within columns, means with a different letter are significantly different ($P < 0.05$), values are means ± one SE. The numbers in parentheses indicate sample sizes.

07:00 on day 1. Indicator in excreta at 18:00 on day 1 was not significantly different from indicator in excreta at 14:00 on day 1 (1-tailed *t*-test, $t = -.6165$, $P > 0.25$). This rapid passage rate indicates that the 2-day adjustment period was adequate to eliminate non-study feed prior to sample collection on day 3 for excreta nutrient analysis.

The metabolizable energy coefficient for *Rangia* clam was significantly higher than that for acorns, wolfberry, and blue crab (Table 2). Protein digestibility for blue crab was higher than that for acorns and wolfberry. Lipid digestibility was lower for wolfberry than for *Rangia* clam and acorns. There was no significant effect of feeding trial on metabolizable energy and digestibility coefficients, and Whooping Cranes did not differ in digestion efficiency.

There were significant differences in nutrients among foods (Table 3). Gross energy ranged from 21.430 $kJ \cdot g^{-1}$ for wolfberry to 0.326 $kJ \cdot g^{-1}$ for *Rangia* clam; crude protein ranged from 41.89% for blue crab to 1.44% for *Rangia* clam. Total lipid ranged from 13.4% for wolfberry to 0.2% for *Rangia* clam, and ash ranged from 96.9% for *Rangia* clam to 2.4% for acorns from Dagger Point.

Wolfberry ranked highest of the five foods for metabolizable energy and total lipid nutrient availability per kg food ingested (Table 4). Blue crab ranked highest of the five foods for crude protein availability.

DISCUSSION

Protein digestibility coefficients obtained for Whooping Cranes for acorns (48.9) and wolfberry (53.4) are lower than those for *Rangia* clam (69.4) and blue crab (75.2); and are similar to the lower digestibilities for plant protein when compared to animal protein (Karasov 1990). Total dry-matter digestibility of *Rangia* clam was lower compared to the other foods, reflecting the high percentage of ash (96.87%) in *Rangia* clam. High metabolizable energy, protein, and lipid digestibility coefficients are expected for shellfish where muscle comprises most of the readily digested dry material (Karasov 1990); the MEC* for *Rangia cuneata* (75.0) was similar (72–73) to the MEC* for intertidal polychaeta (*Pseudonereis variegata*), black mussels (*Choromytilus meridionalis*), and limpet (*Patella granularis*) (Hockey 1984, Karasov 1990).

The MEC* for whole live oak acorn (43.2) was lower than that for white oak acorn meat (*Quercus alba*) (66.0) consumed by Ruffed Grouse (*Bonasa umbellus*) (Servello et al. 1987), and that for pin oak (*Q. palustris*) acorn meat (55.3) and red oak (*Q. rubra*) acorn meat (57.3) consumed by Northern Bobwhites (*Colinus virginianus*) (Robel et al. 1979). Non-digestible cellulose and hemicellulose together comprise approxi-

TABLE 2

APPARENT METABOLIZABLE AND DIGESTIBLE ENERGY, DRY MATTER, CRUDE PROTEIN, AND TOTAL LIPID DIGESTIBILITY COEFFICIENTS (%)[a]

Factor	Digestibility coefficients				
	Crane breeder feed	*Rangia cuneata*	Live oak acorn	Wolfberry fruit	Blue crab
Metabolizable energy	69.2 ± 1.0(5)A	75.0 ± 4.7(5)A	43.2 ± 3.8(5)B	44.8 ± 4.0(5)B	34.1 ± 6.3(5)B
Digestible energy	72.5 ± 1.0(5)A	76.7 ± 5.3(5)A	43.3 ± 3.5(5)B	43.8 ± 4.1(5)B	43.0 ± 5.4(5)B
Dry matter	90.1 ± 0.3(5)A	48.8 ± 3.3(5)C	80.2 ± 0.9(5)B	91.5 ± 1.1(5)A	71.2 ± 3.3(5)B
Crude protein	69.6 ± 2.4(5)AB	69.4 ± 4.4(5)AB	48.9 ± 5.4(5)C	53.4 ± 5.7(5)BC	75.2 ± 3.5(5)A
Total lipid	80.9 ± 1.1(5)AB	75.3 ± 5.7(5)AB	87.2 ± 3.9(5)A	60.0 ± 4.2(5)C	67.1 ± 5.4(5)BC

[a] Means within rows with different letters are significantly different ($P < 0.05$), values are means ± one SE. The numbers in parentheses indicate sample sizes.

TABLE 3

GROSS ENERGY (KJ·G^{-1}), AND PERCENT MOISTURE, ASH, CRUDE PROTEIN, TOTAL LIPID, TOTAL PHENOLS, AND CHITIN[a]

Component	Live oak acorn (East Shore Road)	Live oak acorn (Dagger Point)	Wolfberry fruit (Sundown Bay)	Blue crab (Long Lake)	Stout razor clam (Matagorda Island)	*Rangia cuneata* (Indian Head Point)
Gross energy	19.076 ± 0.158(5)B	18.799 ± 0.032(5)B	21.430 ± 0.057(5)A	11.947 ± 0.415(5)C	4.397 ± 0.049(5)D	0.326 ± 0.015(5)E
% Moisture	41.18 ± 1.87(9)D	17.41 ± 0.91(9)F	76.28 ± 0.25(9)A	72.96 ± 1.09(9)B	56.86 ± 0.46(9)C	26.79 ± 0.38(9)E
% Ash	2.62 ± 0.13(9)E	2.37 ± 0.12(9)E	7.01 ± 0.07(9)D	43.59 ± 0.97(9)C	78.55 ± 0.41(9)B	96.87 ± 0.04(9)A
% Crude protein	4.46 ± 0.08(9)D	4.55 ± 0.15(9)D	19.46 ± 0.31(9)B	41.89 ± 0.72(9)A	14.34 ± 0.37(9)C	1.44 ± 0.02(9)E
% Total lipid	5.45 ± 0.36(9)B	3.53 ± 0.21(9)C	13.38 ± 0.19(8)A	5.28 ± 0.64(9)B	1.74 ± 0.05(9)D	0.24 ± 0.03(9)E
% Total phenols	5.48 ± 0.37(9)B	7.25 ± 0.62(9)A	0.51 ± 0.04(9)C	—	—	—
% Chitin	—	—	—	6.92 ± 0.37(9)	—	—

[a] Means within rows with a different letter are significantly different ($P < 0.05$), values are means ± one SE. The numbers in parentheses indicate sample sizes.

TABLE 4
TOTAL ENERGY AND NUTRIENT AVAILABILITY (DRY-WEIGHT BASIS)

Food	Metabolizable energy ($kJ \cdot g^{-1}$)	Grams nutrient available per kg food ingested	
		Crude protein ($g \cdot kg^{-1}$)	Total lipid ($g \cdot kg^{-1}$)
Wolfberry fruit	9.601	104	80
Live oak acorn	8.121	22	31
Blue crab	4.074	315	35
Stout razor clam	3.298	100	13
Rangia cuneata	0.245	10	2

mately 27% of the total dry matter of whole live oak acorns (Short 1976), and the lower MEC* for whole live oak acorns was expected.

Tannins in foods inhibit protein digestibility (Marquardt and Ward 1979, Robbins et al. 1987, Johnson et al. 1993) and contribute to lower energy utilization in avian species (Servello and Kirkpatrick 1989, Johnson et al. 1993). Total phenolics are lower for acorns of the white oak group (includes live oak) than for acorns of the red oak group (Servello and Kirkpatrick 1989). However, total phenolics (>5%) in live oak acorns collected from the ANWR is high enough to affect protein digestibility and energy utilization by Whooping Cranes, as indicated by the low MEC* and protein digestibility for acorns compared to other foods.

Acorns, wolfberry, blue crab, stout razor clam, and *Rangia* clam were markedly different in nutrient composition (dry-weight). We divided Whooping Crane foods into two categories, (1) high energy-low protein and (2) low energy-high protein. Wolfberry and acorns are high in caloric content but lower in protein. Blue crab and stout razor clam are lower in calories, but have moderate to high protein levels. *Rangia* clam is low in energy and protein and is a suboptimal energy and nutrient resource for Whooping Cranes. Approximately 30× more *Rangia* clam, would have to be eaten than wolfberry and blue crabs to achieve comparable intake of metabolizable energy and protein.

Seasonal availability, relative size of food items, food density, and nutritional value must be considered when evaluating natural foods for Whooping Cranes. Acorns constitute a high-energy localized food resource. However, availability of acorns may be short compared to blue crab, wolfberry, and stout razor clam (Hunt 1987, Bishop et al. 1987, Stehn 1994b). Blue crab and stout razor clam provide 3–5× more digestible crude protein than wolfberry and acorns, are larger per unit capture, but are less localized and may require greater time for search and

processing. Wolfberry is small, and because plants are scattered, energy benefits for wolfberry may be offset by higher energy expenditure and lower rates of energy capture by foraging Whooping Cranes (pers. obs.).

Although we evaluated food quality on a dry-weight basis, moisture content among foods varied by as much as 438%. Variance in moisture of this magnitude may be significant if Whooping Cranes are limited in the amount of food they can consume and if feeding efficiency is affected by food availability. Acorns collected from Dagger Point averaged 17.4% moisture compared to 41.2% moisture for acorns collected along East Shore Road. On a wet-weight basis, metabolizable energy of acorns from Dagger Point was 6.699 $kJ \cdot g^{-1}$ compared to 4.699 $kJ \cdot g^{-1}$ for acorns from East Shore Road. Wolfberry ranked highest of all foods for metabolizable energy on a dry-weight basis. However, on a wet-weight basis, wolfberry provided only 2.275 $kJ \cdot g^{-1}$ compared to 6.699 $kJ \cdot g^{-1}$ for burned acorns.

Under some conditions of food availability, Whooping Cranes on the ANWR may have difficulty in meeting maintenance requirements and building energy reserves needed for spring migration (Iverson and Vohs 1982, Krapu et al. 1985). Foods may have been less available during fall and winter of 1993–1994, because acorns and blue crabs were not common, although wolfberry was abundant into January (Stehn 1994b). Whooping Cranes rarely fed on clams during winter 1993–1994 because refuge clam populations were lower in recent years (Stehn 1994b). Whooping Cranes were more dispersed in 1993–1994, and movements were less predictable, suggesting possible shortage of blue crab (Stehn 1994b). Cranes also migrated late during spring 1994, and an unprecedented 15 cranes remained on the refuge and Matagorda Island until early May (Stehn 1994b). Whooping Crane mortality was also higher than normal: three adults and five juveniles disappeared between 29 November 1993–16 February 1994 (Stehn 1994b). Counts in late 1994 included 131, down five from the spring departure count of 136 (Stehn 1994a). In spring 1993, a record 46 pairs nested; however, only 28 pairs initiated nesting in spring 1994 of a possible 45 known adult pairs (Stehn 1994a).

Multiple factors contribute to Whooping Crane mortality; predation, collisions with power lines, disease, and habitat conditions on the breeding ground (Brown et al. 1987, Garton et al. 1989, Kuyt et al. 1992, U.S. Fish and Wildl. Serv. 1994). It is possible, however, as indicated by the high over-winter mortality for 1993–1994, the late spring migration, lower number of returning Whooping Cranes, and low number of pairs that nested spring 1994, that food shortage on the ANWR was a contributing factor to low reproduction and high Whooping Crane mortality from late fall of 1993 to fall of 1994. Conditions of food shortage on the ANWR, similar to those observed during winter 1993–1994, are of concern if the

observed higher mortality and low reproductive success are related to lowered fitness caused by limited winter foods and the inability to assemble required energy reserves for migration and breeding.

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